Germination of the Seeds of some common cultivated Plants after prolonged Immersion in Liquid Air*

By A. D. Selby

During the winter season of 1900–1901, Mr. J. E. Woodland, of Wooster, who was traveling at the time conducting experiments with liquid air, suggested to the writer the desirability of subjecting seeds to the low temperatures resulting from immersion in the liquid air, and very kindly offered to conduct the immersion if the seeds and the directions for the work were supplied. This generous offer on the part of Mr. Woodland entailed no small labor as he was traveling from place to place and his time was absorbed in his lecture work. It is needless to state that the offer of coöperation was accepted. Packages of seeds of *Ricinus*, *Lupinus luteus*, maize, flax, wheat, rye, cucumber, *Mimosa pudica*, *Onobrychis sativa*, *Pinus sylvestris*, *Cotoneaster buxifolia*, and *Chenopodium album*, consisting of a limited number of seeds of each species, were tied separately in open Swiss cloth and these were collectively for each set united in small bundles. Properly enclosed these were transmitted by mail and returned after immersion in the medium, liquid air. The seeds were then germinated upon moistened filter paper together with untreated seeds out of most of the original packages from which the immersed seeds were taken. By an oversight or by neglect to reserve them, the seeds of maize, *Ricinus*, *Lupinus luteus* and *Chenopodium album* are not recorded in the check lots. The germination of the untreated seeds of the latter is thought to have been good. The seeds of *Cotoneaster* did not prove germinable.

Similar lots of the seeds were also planted in the greenhouse in flats, and while the germinations were decidedly irregular in the soil, they may possess interest. Those who have endeavored to grow many sorts of seeds in soil under glass in the mid-winter season, may be less surprised than others at this feature. The

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lots of seeds consisted of 10 to 25 seeds of each species for germination in soil and tester.

The manner of immersion was by sudden approach of the seeds from room temperature to that of immediate, complete and prolonged immersion beneath the liquid air, the seeds the while being contained in the gauzy cotton, which we may designate "sudden transition," or by gradual approach of the seeds into nearness with the liquid air followed by the complete immersion therein and similar gradual withdrawal, "gradual transition."

Summarized, the treatment of the several lots was as follows:
By sudden transition:

One lot 6 hours' immersion under liquid air.

One lot 12 hours' immersion under liquid air.

By gradual transition:

One lot 24 hours' immersion under liquid air.

One lot 48 hours' immersion under liquid air.

Save the seeds of maize, no apparent change occurred as a result of the low temperature to which they were subjected. The kernels of maize cracked badly, showing that the hardened endosperm could not withstand the stress imposed. It was curious to observe these germinate with fragments of the endosperm missing.

TABLE I

GERMINATION PERCENTAGES OF TREATED AND UNTREATED SEEDS ON FILTER PAPER

NAME OF SEED	Untreated				Immersed in Liquid Air by sudden Transition								Immersed in Liquid Air by gradual Transition							
	Orig. Seeds				6 hours				12 hours				24 hours				48 hours			
	4 days.	8 days.	15 days.	28 days.	4 days.	8 days.	12 days.	23 days.	4 days.	9 days.	16 days.	21 days.	3 days.	6 days.	8 days.	11 days.	3 days	6 days.	8 days.	11 days.
Onobrychis sativa.		8	12	12							4	16			4	4		4	4	4
Mimosa pudiva.		14	34	40		10	34	38			24	48		16	16	16		16	24	24
Pinus sylvestris.			16	18			4	12			20	28				4			4	16
Helianthus annuus.	75	85	85	85	25	90	90	90	80	86	86	86		90	100	100		90	100	100
Cucumis sativus.	28	60	80	80		60	66	66	53	73	73	80		100	100	100		60	70	70
Secale cereale.	90	90	90	90	100	100	100	100	96	96	96	96	100	100	100	100	100	100	100	100
Triticum sativum.	92	92	92	92	96	96	96	96	92	92	92	92	12	96	96	96	12	96	96	96
Linum usitatissimum.	84	86	86	86	80	82	82	82	76	84	84	84	40	72	72	72	36	84	84	84
Zea Mays.	Not tested.				Not tested.					50	50	50		30	30	30		20	20	20
Ricinus communis.	"	"			"	"				60	60	60		50	70	70		30	30	30
Lupinus luteus.	"	"			"	"						0			10	10				0
Chenopodium album.	"	"			"	"				12	76	80		12	92	96		4	68	76

TABLE II

GERMINATION PERCENTAGES OF TREATED AND UNTREATED SEEDS IN SOIL

NAME OF SEED	Untreated				Immersed in Liquid Air by sudden Transition								Immersed in Liquid Air by gradual Transition							
	Orig Seeds				6 hours				12 hours				24 hours				48 hours			
	4 days.	9 days.	13 days.	25 days.	4 days.	6 days.	14 days.	29 days.	4 days.	7 days.	14 days.	30 days.	4 days.	6 days.	10 days.	30 days.	4 days.	6 days.	10 days.	30 days.
Onobrychis sativa				0				4				4			7	7				0
Mimosa pudica				20				0				24				16				16
Pinus sylvestris				7				0				0				0				0
Helianthus annuus		66	80	80		40	60	60		42	42	50		60	60	60	20	40	40	40
Cucumis sativus				0				0				0	7	7	7	7				0
Secale cereale	20	53	53	53	32	76	76	76	16	56	60	60	72	80	80	80	80	84	84	84
Triticum sativum	20	86	86	86	36	68	88	88	16	92	92	92	72	76	76	76	60	76	80	80
Linum usitatissimum		47	47	47		8	12	12	8	24	36	36	12	44	44	44	36	44	48	48
Zea Mays				0	Not tested.							0				0				0
Ricinus communis				47	"	"						50				0			33	33
Lupinus luteus				0	"	"						0				0				0
Chenopodium album				36	"	"					8	40			13	27			16	32

Somewhat of irregularity in the length of the day periods is due to the fact that these lots were handled at different times and equal intervals were not followed.

It is not apparent to the writer that any marked unfavorable effect on germinable seeds may be traced to the immersion, that is, to the extremely low temperature to which they were subjected. Gradations appear with respect to the results of a longer or shorter operation of the cold, perhaps, more conspicuously on seeds of lower vitality. With sunflower, wheat, rye, even the prolonged period of 48 hours has increased if it has in any manner changed the promptness of germination, comparing the more regular germination upon moistened filter paper.*

The temperature of liquid air is stated at — 190° C. Certainly the seeds immersed in liquid air for 48 or even 24 hours would scarcely fail to come to the temperature of the surrounding medium. Physiologists will doubtless agree that only dry seeds may withstand this low temperature. For the agriculturist the experiments of this class enforce a homely injunction to prepare in advance of the winter.

* MacDougal, Practical Text-book of Plant Physiology, 89–91. 1901.

The papers upon this subject by Brown and Escombe, and Thisleton-Dyer did not come to my attention until after my work was finished. Since I find a substantial agreement in the results of the three separate series of experiments no further discussion seems necessary.

The writer would acknowledge his obligation to his assistant at the Station, Mr. John F. Hicks, who has conducted the germination tests.

SUPPLEMENTAL NOTE

Upon going over considerable of the literature relating to the effect of cold upon seeds and particularly upon their germination, one is impressed by the discovery in every case of the survival of the germinative power after subjection to the lowest temperature obtainable at the time of the experiment.

M. Edwards and M. Colin (1834) subjected seeds of wheat, barley, rye and broad bean to a temperature which froze mercury, permitting the seeds to remain for fifteen minutes after which their power of germination was unchanged. Wartman (1860) made his experiments upon seeds of *Linaria bipartita*, *Clarkia elegans*, *Nemophila insignis*, *Lepidium sativum*, *Triticum sativum*, *Hordeum vulgare*, *Avena sativa*, *Portulaca oleracea* and *Eschscholtzia Californica*, subjecting one lot to a temperature of — 57° C. for thirty minutes and another to — 110° C. for twenty minutes after which germination was unimpaired.

Wartman concludes "Il est donc certain que la grand froid que l'homme sache produire ne detruit point la vitalité des graines, et ne l'amoindrit pas le meme," a conclusion which seems to apply without change to the later experiments of de Candolle and Pictet when the liquefaction of gases became more easily attained as well as to the briefly announced results of Dewar and McKendrick (1892), to the extended series of seeds experimented upon by Brown and Escombe (1897) and to the more rigorous conditions but fewer seeds under experiment by Thisleton-Dyer.

The experiments of Brown and Escombe were upon twelve sorts of seeds by subjecting them for 110 hours to the temperature secured by immersion in liquid air which they state as 183 degrees C. to 192 degrees C. The seeds represent a wide range of families and a wide difference in composition.

To the writer the consonance of the results of a long series of experiments by different persons, by subjecting seeds to extremely low temperatures, appeals with its cumulative force. The facts lend a new significance to the latent life of seeds.

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OHIO AGRICULTURAL EXPERIMENT STATION,
WOOSTER, OHIO.